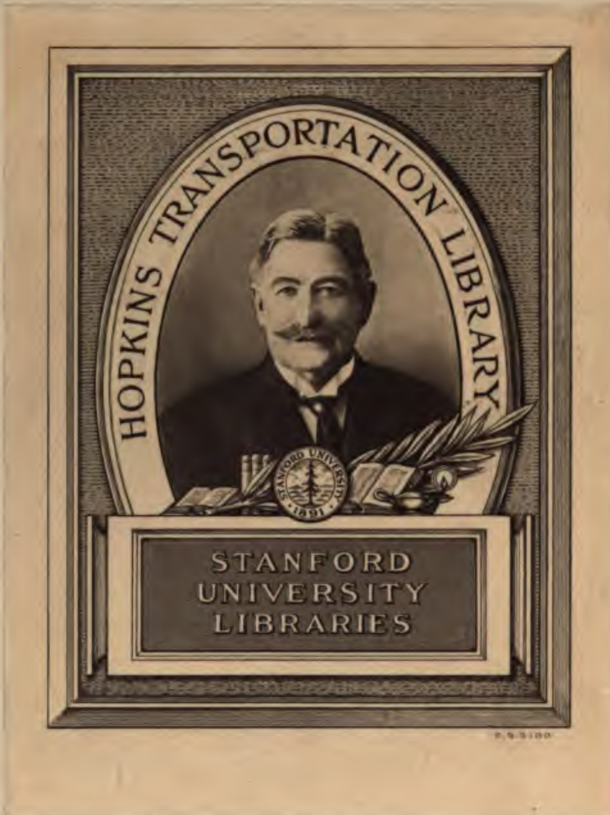
ATMOSPHERIC
PROPULSION

PILBROW

1844.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RAILWAY AND CANAL

PROPULSION,

AND

PNEUMATIC TELEGRAPH.

BY

JAMES PILBROW, C.E.

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SECOND EDITION.

LONDON:
JOHN WEALE, [illegible], HIGH HOLBORN.
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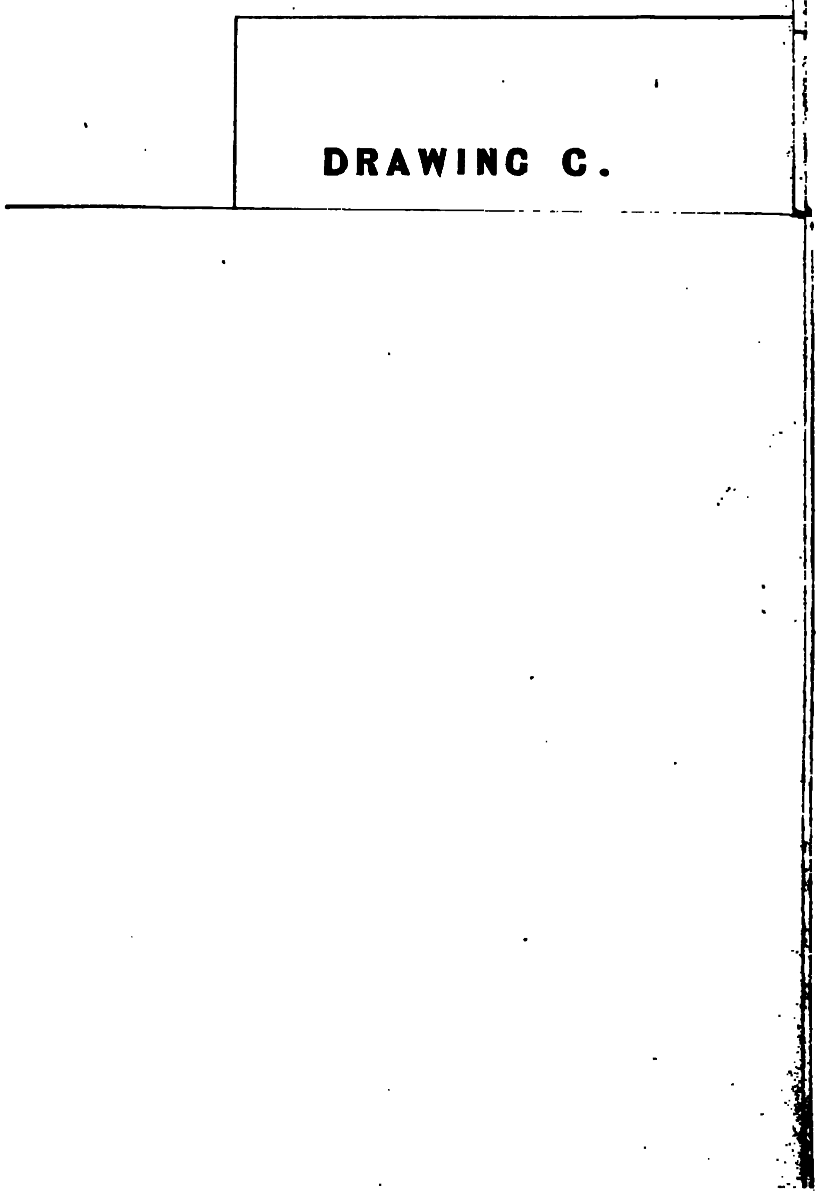
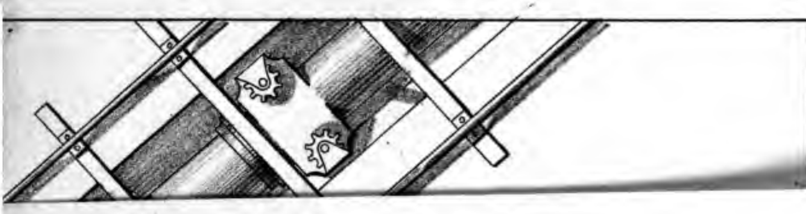


DRAWING C.



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When DIFFICULTIES are accepted, without question, as IMPOSSIBILITIES, endeavour is suppressed, and enterprise extinguished.

SECOND EDITION.

LONDON:
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1844.

Price 2*s*. 6*d*.

CONTENTS.

PILBROW'S

ATMOSPHERIC RAILWAY,

&c. &c.

INTRODUCTORY REMARKS.

As it is with mankind individually, so is it with the aggregate forming an empire—its wants are ever increasing in greater ratio than its means; hence too, in the one, as in the other, there is a constant stimulus to exertion:—and this we are daily witnessing in this great, commercial, and wealthy nation,—a never-tiring spirit of genius, talent, and enterprise developed to meet the demands of a people rapidly and almost unprecedentedly progressing in general education, opulence, and power.

The first great essential in such advance, *is facility of inter-communication between the inhabitants of one part of a country with that of another*, from its centre to its frontiers, and from its districts of production to its ports, not only in *expedition* but *cheapness*, that it may be *generally* used; also, in *safety*, that it may be *confidently* used; a state of things hitherto at direct variance one with the other. Scarcely had we the *Macadamized* road, and the stage of ten-miles-an hour, than this once impossibility was superseded by the twenty-miles-per-hour train upon rails, with steam and mechanism substituted for animal labour. This system, by great mental exertion and mechanical skill, has improved to thirty miles, average. We still rest unsatis-

fied, and are seeking *safer*, *quicker*, and *cheaper methods* in the now popular "*atmospheric principle*" of propulsion, which is more vigorous and promising in its infancy than any other project of similar nature and importance has been at a more advanced stage. Much then may be expected from the developement of this embryo principle, and from its improvements and mechanical modifications. To this consummation I have devoted much time and thought (to say nothing of financial risks and expenditure), and after maturing my plans, and securing them by Letters Patent for the United Kingdom, &c., I now submit them to the public, by giving a description and comparative statement of advantages possessed by this my "ATMOSPHERIC RAILWAY AND CANAL PROPULSION."*

The several plans submitted within the last twenty years to public notice for propelling carriages upon railways by the natural pressure of the atmosphere,† have all had, in common, a main pipe, a piston or diaphragm fitting this pipe, an air pump to exhaust it, and a connecting material between the piston and carriage through a continuous slit or valve along the top of the main pipe; which valve must be ripped up every journey by the passing of the carriage, and cemented down again for the next exhaustion; the

* I have adopted the popular term, "Atmospheric," as the descriptive name of my invention, in common with others, simply because it will *now* best convey to the public the means or impelling power used; though I most decidedly prefer, both for propriety and elegance, the word "Pneumatic," and hope it may ultimately prevail.

† I do not think it worth while to enlarge upon the subject at this more diffused and advanced state of scientific knowledge, to name the several other plans that have been or even now are projected to propel, at the required velocities, by *condensed air*, or water through tubes,—the latter being a most *thoughtless* scheme, to say the least of it,—the former needlessly adding difficulties, throwing away *natural* assistances and advantages, and rendering that which is comparatively simple, cheap, and effective,—complex, expensive and uncertain.

presence of this continuous valve seems ever to have been considered a *sine quâ non,* with all the difficulties arising from it; and to connect a carriage, outside the pipe, to a piston inside, so that the one shall be acted upon by the other, *without this opening,* seems never to have been dreamt of in the philosophy of the several projectors of atmospheric railways, for, says the Editor of the Memoir of Samuel Clegg,* "now as this connexion could only be made by means of a rod or plate attached to the piston inside the tube and to the carriage outside the tube, it is evident that there must be an open groove entirely through the tube from one end to the other, in order to admit the passage of the connecting rod or plate. Here then comes the difficulty:—The tube must be exhausted of air, or nearly so; therefore the groove or opening must be closed up during the process of pumping, and again the connecting plate must pass along the groove, and must open it during the passage of a train, and unless some contrivance be adopted for again closing or sealing up the groove, no other train could be propelled, as the pumps would work in vain in attempting to produce a vacuum." The biographer proceeds to describe the "highly ingenious means by which Mr. Clegg has met these difficulties," that is, by the continuous valve, but which in fact entails upon the system the greatest of its difficulties and objections, which will be found further dwelt upon in the concluding portion of this paper. To say then that I have succeeded in dispensing with this valve entirely, and the continuous opening or slit along the tube, and yet am able to connect the carriage and piston together, so that their motions become dependent upon each other, and that the piston will smoothly and effectually drag the carriages after it to the end of the journey, will appear like tempting the credulity of my readers, or at least, at first,

* Vide Weale's Quarterly Papers on Engineering, part III, p. 11, 1844.

will doubtlessly startle, and cause them to exclaim with those few to whom it was first mentioned, that "it is impossible."—Yet, when seen, it is so simple, that a person with the minimum of mechanical knowledge will fully understand it, and admit its efficiency; and a little reflection will show him the important change which must hereby be made in the prospects and utility of the atmospheric mode of propelling; for few will deny the value and advantages of this principle, when the *long valve is dispensed with, leakage prevented,* and a method of *crossing upon a level without discontinuing the main,* is discovered.

And here, perhaps, it may not be amiss to make a remark or two upon the comparison of the *long* cylinder (the 'main') and the air of the "atmospheric principle," and the *short* cylinder and the steam of the locomotive,"—to see how nearly they are alike, in appearance, and in their elementary principle, though quite unlike in their internal economy. Both are pistons travelling at high velocities within cylinders; both receive their power or propulsion alike, and admitted through an opening; both have to get rid of that medium, which, if it remained before the piston, would neutralize the effect. But in all this, how different are the two in reality and in effect. In the "atmospheric" the pressure is low, the *packing* easy, the *induction-passage* large, the resisting medium withdrawn, (being the power) but through an *eduction passage as large as the cylinder,* an invariable direction and simplicity of action, and no calorific losses, &c. In the "locomotive," on the contrary, the pressure is high, the packing tight, the induction contracted and variable, the resistance of the last-used steam great, and in great measure to be actually expelled by the piston through a small aperture, a very quick reciprocating action, &c. &c. The general results of which will be better understood and estimated, by giving an extract, containing *my* views and estimate of the losses of locomotive engines, as inserted by

an able writer of a pamphlet printed in 1842,* leaving my readers to come to their own conclusion on the matter, as relates to a comparison of the two principles, "locomotive" and "atmospheric" propulsion, with the assistance of the very copious evidence before parliament, and the opinions of such eminent men and competent judges as Messrs. BRUNEL, CUBITT, VIGNOLES, GIBBONS, MALLET, FIELD, FAREY, PAULI, and others; I will proceed to describe my invention, and to conclude by a brief comparison of mine with the plans adopted in Ireland.

* For this extract, see Appendix.

THE DESCRIPTION.

Fig. I. (Drawing A.) represents part of a pipe or tube (in section) supposed to be lying along a railway between the rails, similar to the tube so well known in the various plans hitherto devised for the propelling of carriages or trains on the " atmospheric principle ; but, in carrying out my invention, it is proposed that this tube should lie in a hollow or channel dug in the earth, and be fastened also in any convenient manner to the sleepers. At invervals (say at 30 feet or nearer) along this tube, there are inserted or affixed, spindles with rollers or pinions, *or* small cogged wheels, as shown at *a.* and *b.* and better described by reference to the larger drawing of one such pinion, Fig. XII. made or cast in one solid piece of iron, the upper portion *c.* having cogs or teeth around it, any convenient number, say 10 or 12, and the lower portion *d.* being made the same, so that the cogs or teeth may correspond both in situation, size, and number; the portion *e.* between those cogged portions forms a spindle or axis of connection between them, and projecting as shown at each end, top and bottom, as at *f.* and *g.*, forming centres or pivots to work in bearings, as after explained: by reference now to Fig. X., which represents the tube or pipe in section, it will more easily be seen how this spindle, with its pinions, is placed, and how it acts; the tube has projections cast or otherwise made upon it at the places proposed to place these pinions, and also has an opening in it to allow of the lower portion of the pinion *d.* to enter and project a short distance into the hollow of the tube, as shown at *d,* the upper and lower ends of the spindle, or the pivots of the

pinion working in holes or bearings made for that purpose in this projecting case or box, as at *h. i.*, the box having a support carried up, as at *a.*; but that part of the spindle or axis between the toothed portions does not touch, but passes through a hole or passage made in the tube and "box," which is larger than the spindle, as at *j.*; but there is a flat or conical part, as at *k.*, which is allowed to touch, as will be explained hereafter; these pinions therefore are free to turn when acted upon in any proper manner for that purpose, and are partly inside the tube and partly out. I propose then a piston to be made, (which shall hereafter be more particularly described) to fit as nearly air-tight as possible into this tube, and having attached to it behind a long bar or piece or pieces of iron, or some other suitable material, having cogs or teeth along its edge or edges, to correspond and fit the cogs or the teeth of the pinions. Figs. II. and III. represent such a piston and appendage, which I term the "piston rack," here shown as a *double* one, that is, having cogs on both edges. Fig. II. shows a side view, and Fig. III. a plan or top view; *l. l.* represents the piston head, and from thence to *m.* the line of cogs or teeth; *n.* is a wheel or roller placed near the centre of the rack to support it in its proper place, and to obviate friction in its progression. Fig. IV. represents the end front view of the piston, and Fig. V. a section of the rack portion cut through the dotted line ⏀. ⏀. The cogs do not pass quite through or entirely down, but along the lower part there is a plain piece, as shown at *o. o.* which at the piston end declines or approaches the bottom, forming a small inclined plane, as shown at *p. p.'* there being no cogs at the very commencement *p.'*; this "piston rack" is to be sufficiently long to reach two or more of the pinions in the tube, that it may never be entirely free, that is, will touch one before it leaves another; the pinions being then so arranged, that they project at about the middle or horizontal diameter

of the tube, and the rack being arranged in the same position as to the piston, so that when the piston is placed in or allowed to pass along the tube, the "rack" or cogged edges will act upon and be in gear with that part of the pinion at *d.*, and if a vacuum be formed by pumping out or exhausting the air from the front of the piston in the usual and well known manner by air pumps worked by steam engines or otherwise; the pressure of the natural atmosphere will urge this piston onwards towards the vacuum, if permitted to do so, and consequently the "rack" with it, and that being in gear with the pinions, cannot advance without turning them as it passes, and therefore that portion of the spindle and pinion which is *outside* the tube as at *q*, *q*. Fig. I. There may be pinions on each side of the tube opposite each other, as shown in Fig. VI., if advisable, which will render it necessary that the "rack" should be double, or cogged on both edges, as shown; and hereafter I shall describe and consider this to be the case throughout the following descriptions, as being the most comprehensive form, although *single* "racks" and "pinions" may be found generally the better plan in practice, where the difference is merely the use of one pinion instead of two, as before described, and the "racks" being cogged only on one side; the "carriage rack," in this case having a guide to keep it to the pinion, which guide may be a plain upright, or a plain or uncogged pinion in place of the pinion so removed.

Fig. VI. is a top view of the tube, and shows two pairs of pinions, *q.q.q.q.*, which pinions must be kept as nearly as possible at equal and the same distances laterally. To the under part of a railway carriage, in any convenient manner will be attached a similar "rack" to the "piston rack," (but without the piston or plain part, as at *o. o.* in Fig. II.) which I call the "carriage rack," such a rack is shown in plan by Fig. VII,—the front end *r.* being tapered

or pointed to render easy its entrance between the pinions, and being made, as also the piston rack, as light as consistent with the necessary strength, by being in the form of frame-work, or hollowed as represented; *s. s.* are places where it is attached to the carriage, as after described, Fig. IX. represents the front view; this "carriage rack" is made precisely to correspond with the internal or "piston rack," and will be the exact width the pinions are apart, so as to be in gear, like the "piston rack," with the two opposite pinions at one and the same time; this rack is also the length of the other, so that it may reach two or more of the pinions or pairs of pinions at once. Fig. VIII. represents a side view of the "carriage rack," and Fig. XI. a transverse section of the tube, with opposite pinions, (supposed to be taken through the dotted line λ.λ. of Fig. VI.) showing also a section of the carriage rack at *t t.* (as cut through the dotted line ϩ. ϩ. Fig. VIII.) and a section of the "piston rack" at *u.*, both racks being in gear respectively with the pinions at v.v.v.v.: therefore, by placing the rack, as represented by Fig. VII, upon Fig. VI. in the position, they are there separately shown, and in such a manner as to place the pinions in gear with the cogs on each side of the rack, also that the ends of the "piston rack" inside the tube, and the "carriage rack" outside, shall correspond, and this will be the relative position in which it is intended to place them. The boxes or projections, w.w.w.w. which contain the lower part of the pinions, will have a hollow or chamber, to permit the pinions to revolve freely, but to be made and put on to the tube air-tight, having but one opening into the inner part or chamber, viz. at *j.* (Figs. X. and XI.) through which the spindle of the pinion passes. To admit of the pinions being put into their places, the boxes must be made to separate and to go together at the dotted lines, x.x.x.x.x.x.x.x.x.x., by bolts, shown by the letters *y.* and air-tight, (Figs. VI. X. and XI.)

To make the passage of the spindle from exterior to interior of the tube air-tight, when required to be so, I make or turn upon the spindle (below the upper cogged part) a flat shoulder, or a conical or bevelled shoulder, at an angle of about 45°, as shown at *k.* (Fig. X.) and on the upper edge of the passage through which the spindle passes, *(j.)* I form also, bevelled, and truly grind the conical part of the spindle to this part, so that when down in its place, the conical part of the spindle fits and becomes air-tight, in the manner of the common valve known by the name of the "spindle or conical valve," and thus prevent the admission of air through or by this passage; or instead of making the part conical, I make a *cupped* or simple *flat* shoulder, ground true to the edges (horizontally) of the upper part of the passage; and which plan I now give the preference to, being more simple and durable. Another method is a combination of the former two, as shown by Figs. XI & XII, where instead of the flat shoulder is a flat plate or disc, through which the spindle passes, having a conical part ground to a corresponding surface in the plate, as at *z.* Fig. XII. This modification is for the purpose of diminishing the friction, when the passage is required to be large, in case of the pinions turning round when pressure is upon them, thus permitting the smaller circumference of the two (the conical) turning instead of the larger flat one at its outer edges, where it will lie upon the "pinion box" at 2. 2. 2. 2. Fig. XI. That the spindle may be lifted up, and therefore the shoulder or cone also from its seat, (as shown by the pinions in Fig. XI.) the pivots are made long enough and the "chamber" in the tube and "box" large enough to permit of it. When the pinions are lifted up, a free passage is allowed for the ingress of air into the tube; and to make this passage under these circumstances as large and free as possible, several side passages may be made also, as shown at 3. 3. 3. 3., Figs. X. and XI. When the "piston rack" is within the tube in its desired situation, and the cogs of the pinions in gear with those of the rack,

the lower surface or end of the pinion cogs 4. 4. Fig. XI. will rest upon the plain piece (before explained) on the "piston rack," which makes a kind of shelf or ledge for the cogs or teeth; and thus, if this rack is so arranged as to move in a line rather higher than the pinions are placed when down, (as in Fig. X.) it will cause them to be lifted up when it passes them, thus avoiding the friction of the air-tight shoulders, and permitting as much air to enter into the tube during this action as may be essential to the efficacy of the apparatus, as will be further explained hereafter.

If preferable, the upper pinion may be constructed shallower, and therefore lighter than is shown at *c*. Fig. XII. in the manner represented by or in Fig. XI., but in this case, the edges or cogged part of the " carriage rack " must be made deeper, as shown by the section Fig. XI. at *t. t.* to allow for the rising of the pinions and any small irregularity of the level in working, or of the carriage or rails of the railway.

The " carriage rack " may be attached to the under part of any railway carriage (the first carriage of a train) by any suitable means, but I prefer the following mode of doing it, which will be understood by reference to Figs. VII. and VIII., Drawing A. The two parts 5. 5. Fig. VIII. I firmly fasten to the under part of the carriage, or to a piece of timber supported by and suitably attached to the axles of the carriage; see also the dotted drawing Fig. I. In the under part of these supports is formed a groove or slot 6. 6. Figs. VII. and VIII., and upon the rack are fixed suitable projections, 7. 7. through which bolts 8. 8. are passed, going also through the slot in the support, these bolts then resting at the bottom of the slots, support the rack in the horizontal position shown, a little lateral play being allowed; by this arrangement, the rack, if meeting with any resistance suddenly in any of the pinions in passing them, (the

momentum of the carriage urging it on) would cause the rack to be pushed up these slots, and thereby getting *above* the pinions, if made sufficiently effective for this purpose, and so enable it to pass the obstruction without concussion to any part of the apparatus outside the tube.

Another arrangement and modification of this method of propulsion, and the one I give the preference to, being more simple, I will now describe, reference being had to the figures on Drawing B. The general principle has been explained in the foregoing description, &c. The tube or main in this arrangement being cast or formed with a square hollow channel or passage on its upper part, as shown in section at *a.* Fig. IV., as cut through the line ◎ ◎ Fig. I. and running its entire length, having an opening or slit of communication, *b.* between the square hollow and the interior of the main *c.*; as before described, this "main" is to have, at intervals of twenty or thirty feet, spindles and pinions, but not to reach lower than the square hollow upon the main, and fixed and enclosed, as will be understood by the following, and reference to Figs. I., II, and III. The *main* will be formed as usual of lengths of pipe joined together by socket joints and cement, except that I here propose to cast upon one end of a certain and convenient number of these lengths, a more solid portion, which will form one half of the enclosure for a pair of pinions, with their supports, &c.; such an end is represented in end view by Fig. II., with the pinions, &c. in their places; and two such ends when brought together are represented in top view by Fig. III. and in section of main by Fig. I. Through this more solid part the square hollow and the main passage pass as through the other portions. This simply being for the placing and enclosing the pinions, and therefore in it are made two hollows, *d. d.* Fig. II., for the reception of them, as shown, having also bearing holes at *e. e.* for the lower pivots or centres to work in, (but deeper than the

pivots are long, that the pinions may rest upon the shoulders at *f. f.*) and a passage to permit the spindle or axes of the pinions to pass through as at *f. f.*, also the supports *g. g.* having bearing holes for the upper pivots, as at *h. h.*; all these will be in each portion a half of the necessary whole, as cut through their diameter, (as by the lines σ. σ. σ. σ. Figs, I. and III.) so when two are brought together, as in Figs. I. and III., they will form a complete whole, and enclose the pinions as desired, the parts being bolted together by screw bolts, as at *i. i. i. i.* in Fig. III., and made air-tight by cement or by a little packing laid in a hollow, which may be made to run round, as shown at *j.* Fig. I. All the other joints of the main may be the common "socket joint;" and I propose there should be one or two such joints between every two of these pinion joints, when, if each length of pipe be ten feet, it will make the pinions twenty or thirty feet apart.

It will be seen, then, that the lower pinions here are not to enter the "main" tube at all, but to project in a similar manner into the square passage, as at *k.* Fig. II.; and therefore the pinions (both top and bottom) will approach each other more nearly. A sufficient space is to be allowed at *d. d.* and *l. l.* to permit the lifting up of the pinions, and the passages through which the spindles pass as at *f. f.* are to be made sufficiently large, that when the shoulders or conical parts are lifted away, a free passage may be made for the ingress of the air. These spindles and pinions are formed as before described, with the exception that the under part of the upper pinion is circularly formed, as represented at *m. m.* Fig. II. Between each pair of pinions are fixed by hinges on the top of the pinion chamber, two pieces of iron, in the manner and form as represented by the sections at *n. n.* Fig. II., and side and top views, as at *n. n. n.* Figs. I. and III., which are so made and arranged that their centre of gravity will be on the side nearest each

other, so causing them to fall and touch together at top, as shown in Figs. II. and III., and having a stop at the bottom near the joint at *o.* (Fig. II.) to prevent either of them falling past the centre of the tube. The upper part of these, which I will call "guides," are circularly formed in two ways, as shown in section at *m. m.* Fig. II., and longitudinally as at *n. n.* Fig. III. These guides, then, having liberty of movement backwards or towards the spindles, will, if any substance or body be forced in between them, be separated, and the part *m. m.* (Fig. II.) will be pressed against the circular part of the pinions, and will therefore lift them up; this action and situation is shown by the dotted lines in Fig. II, of one pinion only, the part *p.* being a sectional representation of the substance or body between the pinions, that is, the "carriage rack," as after described. These guides, then, serve two purposes,—they project diverging from each other on either side of the pinions, as *q. q.* Figs. I. and III., forming guides for the entrance of the point of the carriage rack between the pinions, and also by being pressed back by the same, will lift the pinions up.

In Fig. I. is represented the piston in section, having attached to it the "rack" or cogged part, and how I propose to make it, I will now proceed to explain. Upon a strong iron bar *r.*, having shoulders and screws at each end, as shown, I place in the order represented several discs of iron, wood, and leather. Thus, I form the disc *s.* as shown by the sectional figure given, of iron, having a hole through the centre to fit to the smaller part of the bar *r.*, and to go home to the shoulder; this disc is made at the extreme edge or point, the diameter of the main, or nearly so. Next to this I place a disc of thick leather, or other suitable material *t.*, of rather larger diameter. Again, to this I place another disk of iron *u.*, formed in the shape shown in section, that is, dished or concave on the inner side to correspond with the convexity of the disc s., which

also having a hole in the centre, and being placed upon the bar and pressed up, will cause the leather or other material *t.* to take the form shown; this disc will be nearly the diameter of the hollow of the "main." Before this may be placed a conical block of wood *v.*, and when all screwed up together by the nut *w.*, will form the one part of the piston, the leather expanding against the inside of the tube and rendering it air-tight, or nearly so; at the other end of the bar the same arrangement is repeated in the manner shown, making a double piston, for greater security in passing the pinions, and steadiness of travelling. (In the piston in the former plan, as represented at Figs. II. and III., Drawing A, the leathers and discs are so arranged as to form and only occupy the space of a cog of the rack, so being capable of passing the projecting pinions in the main; this arrangement of parts and general form is shown at *l. l. g.g. l.l.*, where there are intended to be four leathers to the complete piston, and two bars and nuts to keep them all steady together; but I prefer the plan above described.)

Returning now again to Drawing B, the manner in which I here form the piston rack, and attach it to the piston, is thus. I have a rod of iron or steel, of suitable strength, rather longer, at least, than the space between two pairs of the pinions on the "main," so that it may be between or in contact with one pair before leaving the other. This rod having a strong "eye" formed at one end, and bent down as shown at *x.* Fig. I. (Drawing B,) and the eye placed upon the end of the bar *r.*, and fastened up firmly to the wooden cone *v.* by the nut *w.*,—the principal part of the rod itself will be in the square channel upon the main, passing up through the slit or opening. Upon this rod I place a number of pieces of iron, wood, and caoutchouc, or other material, (to fill up its entire length) of the shape shown by three views in Figs. VII., VIII., and IX., each having a hole through it the size of the steel rod, which

when placed regularly against each other, as shown by Fig. V. (side view) and Fig. VI. (top view) will form a double line of cogs, being made the proper size and shape to match with the pinions. When a sufficient number of these are placed upon the rod to make the required length, they are all secured on and kept up tightly together by a nut screwed on and secured to the extreme end of the rod, which then forms the "piston rock,;" and the same being very nearly the size of the square channel on the main, will pass along when dragged by the piston, and will come into contact and gear with the lower pinions as it passes between them. The first few cogs, say six, at the end *y*. (Fig. I.) I would make of caoutchouc, or other elastic and tough material, (unless a plain surface in advance should be found preferable) to prevent concussion, &c., and rather larger than the others, so that they might fit the square channel, filling it, making as it were a piston to this channel, the first one or two having a part projecting downwards through the slit, as at *y*., to fill up the slit and resting upon the top of the piston, as at *y*.; the same may be repeated over the hinder part of the piston at *z*. Next to these six elastic cogs, I would place about nine cogs of tough wood, and then fill up the rest of the rod with iron ones, unless wood or other material should be found preferable.

This, then, forms what I call my piston and "piston rack," as represented in its place in Fig. I.; so much of the "rack" 2. 2. being shown as the drawing would allow. The manner I form my "carriage rack," (for this plan) is shown by Figs. X. and XI. (Drawing B,) Fig. X, being a side view of a portion of it, and Fig. XI. a top view. 3.3.3. is a plate or thin bar of iron, or other material, of suitable width and thickness, being pointed and rounded at its ends, and being long enough to reach at least two pairs of the pinions on the "main" at once. On each side of this plate are to be rivetted pieces of iron, or other suitable material, in the form and manner shown at 4. 4., at equal and proper

distances apart, which will, when done, along the length of both sides of this plate, form a line of cogs on each side, being made the suitable size and distance apart, to correspond to the pinions; the rivets are represented by the dotted lines at 4. 4. as running through and fastening two opposite cogs at once. This forms what I call my "carriage rack," and may be attached to the under part of the railway carriage or axles, in a similar manner, as before described, (having, however, two portions beneath at each place instead of one, with the slot or channel 6, Fig. VIII. Drawing A, so that the carriage rack may ascend *between them* when necessary; the "rack" being here too narrow to admit of the other arrangement,) or in any other convenient manner.

The Figs. I. and X. (Drawing B,) show the intended relative situation of the "piston rack" and "carriage rack," the piston being a little in advance of the latter. If desirable, every carriage in a train behind the first one may have a suitable bar of wood, attached in a similar manner as the rack is upon the first carriage, to act like it upon the "guides," and so to keep up the pinions a longer time, thereby giving greater access to the atmosphere behind the piston. This arrangement, also, may be made with *single* pinions and "racks," though here explained as *double*, and in many cases with the advantages of simplicity and cheapness; when the only difference will be as before explained in the former arrangement.

The arrangements herein before described, and referred to for rendering the motion of a piston driven by atmospheric pressure available for propulsion, will admit of various modifications; as for instance, ropes or bands of leather, or of other material, may be employed acting on plain pinions or rollers, in place of the "racks" and pinions, or in connection with a rack and pinion, the motion of the spindle about its axis being occasioned and employed for the purposes of propulsion, either by adhesion and friction

altogether, or by adhesion and friction conjointly with a rack and pinion; but under ordinary circumstances, and for general purposes, I prefer that the motion of the piston should be transmitted by the agency of racks and pinions,as particularly described; but when great velocity of travelling is desired, plain surfaces with suitable rope or bands, instead of cogged pinions and racks, may be used with advantage; in which case, I would have *every* carriage of a train to be acted upon by the spindles, &c. It will also be obvious that instead of the spindle rising and forming a valve for admitting the air behind the piston, the spindle might be fixed (turning only about its axis in air-tight sockets), and the air might be admitted behind the piston through openings at intervals, as the piston and train passed on, but I prefer the arrangements particularly described. I have thought it unnecessary to give any directions respecting the production of the vacuum by pumping, this and other details forming no part of my invention, and being well known to persons conversant with the present system of atmospheric propulsion.

The operation of this invention, or manner of its working, is as follows. A pipe or tube, as before described, of sufficient diameter, being laid along in a hollow between the rails of a railway, and being exhausted of air, and having the spindles and pinions arranged as described at intervals throughout its length; the piston with its "rack" attached is placed in this tube in the manner before explained at the farther end from where the air has been or is being exhausted or withdrawn, the "piston rack" being in gear with the pinions *inside the tube;* a railway carriage, having a "carriage rack" attached to it, as described, being placed upon the rails, as shown by the dotted figure at Fig. I., Drawing A., this "carriage rack" being also in gear correspondingly with the pinion on the upper part of the same spindles, *outside the tube,* that is to say, the relative position of each rack being the same, the "piston rack" being precisely under and matching end to end with the "carriage rack," (un-

less, as in the latter plan, the "piston rack" being longer than the other is a little in advance of it,) the one rack cannot therefore move backwards or forwards without turning the spindles and pinions, these being also in gear with the other rack, *that* must move also, and in the same direction: if the vacuum, then, has such an effect upon the piston, that it advances, the "rack" upon the carriage will be affected, by and through the medium of the spindles and pinions, and will advance also, and keep its relative situation exactly with the other, the racks being long enough to reach as described, at least, two pairs of pinions at one time, the next in advance is acted upon before the one acting has ceased, and therefore as long as the power applied continues, and the piston advances, the carriage will do the same to the end of the tube, neither arriving before or after the other, but together, as they cannot separate, nor can one move or stop without the other; thus would the carriage be propelled, and others, if attached to it.

As it is necessary and important that the atmosphere should be admitted as nearly behind the piston as possible, the spindle and pinions may be lifted up by the advance of the "piston rack" as in the *first* plan, or by the "carriage rack" as in the *second* plan, described before, and the air will enter through the space allowed by the lifting of the conical or flat portion of the spindle or axis of the pinions, as stated; thus would there always be, at least, two or more such passages open, as the "rack" may act upon any required number of pinions. After the rack has passed by, the spindles by their own weight fall into their original places, and thus make an air-tight tube ready for the next exhaustion, when, if an air-pump be set to work at the other end, and the *direction* of the piston and rack changed, and placed again as before into proper gear, the carriage would *return* in like manner.

Drawing C. represents at Fig. I. a plan or bird's-eye

view of a portion of an atmospheric railway of this description, crossed, *on a level,* by a roadway, and another line of atmospheric railway; and Fig. II. a longitudinal elevation and section of such an arrangement, by which it will easily and plainly be seen that there is plenty of space between the pairs of pinions for the crossing of roads, and that the mains being sunk beneath the surface of the ground, or under the sleepers of the rails, they are entirely out of the way, the carriage rack passing on from one pinion to another, over such roads, without interfering—showing also, that where it may happen that two tubes are required to cross each other, one will pass beneath the other, the upper one keeping its level course, the lower one taking a gradual descent or dip under it, the pinions keeping their necessary level at the upper part by being lengthened, at such a locality, in the spindles or axes and supports, as shown at *a.* Fig. II. The first or "rack carriage" of a train is shown advancing upon this cross line as it would appear just previously to its taking the pinions at *a.* This drawing represents the first plan described; the latter would differ in having the "channel" along the top of the "main," and having the pinions closer together (laterally), &c.

As there will not be required by my plan, even in a single line of rails, any discontinuance of the main tube but at a place arranged for trains to meet and cross, which will always be at a *station,* (and for general purposes not less than twenty miles apart,) it will be only at such places that the main will require any kind of valve to close its open end. Fig. XIII., Drawing B, represents such a crossing, *a.* and *b.* are the mains connected with the air pumps by pipes under ground, as at *c. c.*: *d.* is the situation of the engine, &c.: the mains being discontinued at *e.* and *f.*, and the rails made to take the direction as shown, that the trains arriving here would each take one of the sidings, *g.* or *h.*, and thus pass each other. The end of the main would simply require a disc of iron or wood placed against

it, with a little composition, to make an air-tight joint, when the vacuum is to be made by the air pump at *d.*, which disc or valve will fall or be pushed aside when the piston arrives at the end, and will require no more attention, excepting being replaced or closing by the time this engine (*d.*) is again required to work.

The piston would, when it arrives here, either partially or wholly leave the tube, after displacing the disc or door at *e.* or *f.* by its remaining momentum, and the train with the "carriage rack" will pass on, and take one of the sidings *g.* or *h.* and be stopped by the conductors by "brakes" as usual; but the operation of the stopping would have been begun before arriving here, the train now only moving slowly and with sufficient momentum to carry it to the place required, or middle of the siding. When the piston and rack reach the end of the main, and are out or withdrawn, I propose there shall be placed at each of the two ends of the mains *e.* and *f.*, (and all similar ends), a receptacle or trough mounted upon four wheels or rollers, so that the piston coming on to it, could be immediately removed for inspection, &c., and another piston newly greased &c. brought and placed (by the same means) with its head in the tube ready for the next returning train. The trains having both arrived, each train would be (by any suitable means) urged on to the commencement of the opposite "main," where the fresh pistons having been already inserted (and held by any convenient contrivance) and the vacuum formed, the carriage rack coming into gear with the first pair of pinions near *e.* or *f.* and the piston released, the train would start on its journey. Thus the pistons would never leave the main, or enter another, but at a very slow pace, and at a place for stopping; and also that the same piston is not required to go on the whole journey, but a fresh one every twenty miles, leaving the other to be examined, &c. The dotted lines from *e.* to *i.* and from *f.* to *j.* represent the continuance of the hollows

or channel in the ground turning to one side, running under the rails, and ascending to the surface level, by which the pistons are removed and replaced. Several other arrangements might be adopted for the foregoing purposes, but the one here described may be as good as any.

I also should prefer that the spindles and pinions situated near the crossing stations should not be lifted up for the admission of air, as the others, and therefore they would not require the apparatus or parts *u. u.* Figs. I. II. and III. (Drawing B.) for that purpose; by this arrangement the piston would have less force impelling it, as the air not continuing to enter, that which is in would be rarefied or attenuated, and not only assist in stopping, but would be so much done towards the next exhaustion which is immediately to be made (if a valve were introduced to shut off for this purpose,) thus economising time and power.

When this method of propulsion is used upon COMMON ROADS, the tube will be sunk or buried along the side or centre of the road, and its operation would be as before described, there merely being the absence of the rails.

When used as a means of propulsion upon RIVERS or CANALS, the tube may be smaller, and laid either at the edge of the water, or upon piles or posts along its centre, the "rack" being affixed to the bows or side of the vessel to be propelled, to which may be attached any others that are intended to be drawn with it, thus making as it were a train of vessels: the general operation in other respects would be the same as described for carriages upon railways.

THE PNEUMATIC TELEGRAPH.

Along the line of railway, road, or canal, there may be laid down a small tube or tubes, such as are used for gas, about half an inch diameter in the bore, and put together air-tight; these tubes would terminate in any suitable place at each station, by having their ends brought up and bent round, having a portion of glass tube fitted on, and that made to dip into a vessel containing mercury. Near the end or part where the glass portion is af-

fixed, there will be a branch pipe leading to a receiver or air-tight vessel, this branch pipe having a cock or valve, so that communication could be made or shut off at pleasure between this receiver and the long tube; this receiver would be connected with the air pump by a pipe or valve, so that a vacuum would always be easily procured, and maintained in the receiver. Fig. XII. (Drawing B.) represents such an apparatus, *a. a.* being pipes leading to the next station, Y., and *b. b.* being the branch pipes leading from the pipes or tubes *a. a.* to the exhausted receiver. (*c. c.*) are the cocks, and (*d.d.*) the glass portions dipping into the mercury contained in the vessel (*e*); these glass parts I call the "Indicators," as each of them will show, if the mercury rise within it, (which will be the case if the air in the tube connected with either, be rarefied, by opening the cock or communication between it and the receiver at the other station, within which is to be preserved a vacuum, or nearly so.) The operation of, or manner of using this apparatus, which I term my "Pneumatic Telegraph," is simply for a person to make the communication between the vacuous receiver and the tube at a station Z., when almost at the same instant the same would be indicated at the station Y. (whither the tube is carried) by the mercury rising in the glass portion, as shown at *f.*, so that if one or more of these tubes were laid from station to station, and any particular meaning agreed upon for the action or rising of the mercury of any one or more tubes, as "Stop," and "Go on," in Fig. XII., a signal can be conveyed as to the stopping or setting on of the engine, &c. &c. (for which use it is intended.) The tube may be attached to the sleepers if necessary along the line, or buried. Two tubes I consider all that would be necessary upon an "Atmospheric Railway," one to indicate by its action, "Stop," the other, "Go on." These tubes could be made to permit of being acted upon in any part of the line between the stations, by having places where a pipe could be attached, and a vacuous vessel carried by the train having a pipe to fit on, &c. If preferable or necessary, a small float connected with an alarum or bell may be inserted in the mercury at the foot of the glass tube (when it would be necessary for each tube to have a separate vessel), the rising of the mercury in the tube would lower it in the small vessel, and thus the float sinking, might be made to act upon the "detent" of the alarum, and so enable it to give notice by a sound, or strike upon a bell, in case of the person not looking at the indicator, &c.

CONCLUSION.

Comparative advantages of Pilbrow's Invention over the *present* Atmospheric system :—First,

IN CONSTRUCTION.

I. In having no discontinuance of the "main," and therefore no "section valves," &c. at crossings of roads, lanes, &c.

II. In having no necessity for bridges for cross lines, roads, lanes, &c.

III. In having no continuous valve with all its complication, and necessary care in fitting, composition, &c.

IV. In having fewer engine establishments, one to every *ten miles* being sufficient, instead of one to every *three miles*—thus saving *twenty-three engines &c.* out of thirty-four in 100 miles. The reason why a less number will be required on this plan than the other is, that there being no long valve here, the leakage will be so diminished that it will amount to less in ten miles than now in one ; it is estimated that now the leakage equals 5-horse power per mile,* and therefore should there be but one engine to ten miles of main, 50-horse power out of the 100 would be lost for leakage alone, so it is found absolutely necessary to have one engine every three miles, thus reducing the loss to 15-horse power out of the 100. Why the pinion-valves as proposed will not leak so much as the long valve is, first, because the surfaces are ground truly, and are pressed together by the weight and fall of the pinion, (and the more used the better they will stop) ; and secondly, on account of the small quantity of surface or space *that can leak*, the proportion being as 1 to 20 between the two systems, for the

* See Mr. Samuda's evidence before the Committee of the House of Commons. Mr. Bergin, in his evidence, said 5 or 6-horse power per mile, &c., but doubtless this will be found under-rated for extensive practice.

pinion-valve or seat being but about 9 inches in circumference at the aperture where the air is admitted, and being only two of them to every 30 feet of main = 1·5 feet, whereas, the present long valve would be the whole *thirty feet* exposed and liable to leakage; hence, even were the pinion-valves to leak as much as the long valve, *surface for surface,* this plan would only leak 2½-horse power instead of 50-horse power, in ten miles!

V. In there being no necessity for the main to be cast thicker at the lower part than at the top, for strength, as now the tube being with an open groove along its top, when therefore a vacuum is made within, the superincumbent atmosphere pressing all round the tube, has so large a surface to act upon and so strong a tendency to press these edges together, that it is found necessary to cast the "main" much thicker aud heavier at the lower part and altogether than otherwise would be requisite, if it were without any cut or open groove.

VI. In having no necessity for the "heating apparatus."

VII. In having no necessity for 'cranes,' or elevated rails,* for the taking on and off carriages, as that would be done in the usual manner, &c.

VIII. In, that this arrangement will permit of the "main" being varied in its diameter at different parts of a long line, to suit any irregularity in the general level or gradients, or traffic, which is often greater at one part than at another, so that for instance, the tube *a*, (figure xiii, drawing B) from this crossing to the next might be 15 inches in diameter to suit a generally steep inclination or heavy local traffic; and the tube *b*, to the next crossing in the opposite direction might be only 10 inches, sufficient perhaps for a nearly level way or light traffic—an advantage not only in convenience, but in first outlay and construction:—Secondly,

IN SAFETY, AND THEREFORE GREATER POPULARITY.

I. In there being no necessity for a discontinuance of "main" between the stations, therefore—

* See Examination of Mr. Samuda, Committee of House of Commons.

II. In the fact that the piston will never leave one part of the main and enter another at full speed.

III. In there being no section valves under the doubtful control of an attendant, or the liabilities of machinery to get out of order (and so not act at the *instant* required), which neglect or accident would be attended with the most fearful concussion and consequences.

IV. In the piston never leaving or entering a "main" but at a station where it is required to stop.

V. In no liability of obstruction or destruction, by snow, frost, and bad weather.

VI. In being able to retard trains in descending inclines, by not lifting the valves, and thus rarifying the air behind the piston.

VII. In the ability, in case of stoppage or accident between stations, to disengage the piston, and thus send that information to the next station, and then the facility by which a carriage, containing men and tools &c. can be dispatched to their assistance :—Thirdly,

IN SIMPLICITY.

I. In having no heating apparatus and composition.

II. In having no long valve, or section valves, between stations, bridges, &c.

III. In having so few engine establishments, &c. &c.

IV. In being able, without any alteration from the present mode, and without cranes, or elevated rails, to remove or place carriages upon the line :—Fourthly,

IN CHEAPNESS OF FIRST OUTLAY.

I. In requiring fewer engine establishments.

II. In requiring no bridges, &c. for crossing of roads,&c.

III. In greater simplicity and lightness of "main."

In the above three items and founded upon Messrs. Clegg and Co.'s own calculations, and evidence before the House of Commons, the saving in 100 miles would stand thus:

		£.	s.	d.
By the present system, there would be 34 engines and establishments required, at £5000.*	170,000 0 0			
By the proposed system, at ten miles apart, 11 at £5000	55,000 0 0			
		115,000	0	0
By saving in bridges, &c. for roads and cross lines: Messrs. C. & S., in their pamphlet, p. 20, have allowed £2000 per mile extra for bridges, but allowing that half the quantity would be required upon the common locomotive railway, I consider £1000 per mile on the average of lines a very moderate calculation, 1000 × 100		100,000	0	0

By simplicity and lightness of "main," the estimate given of the present plans, by Messrs. C. & S., stand thus, per mile:

	£.
Main, (15-inches diameter)	1632
Long valve, &c.	770
Composition for lining and valve....	250
Planing, drilling, &c.	295
Laying, jointing, &c.	295
Station valves, and piston apparatus .	100
	3342*

The saving in the above may be safely taken thus:

	£.				
In main, (less weight, &c.)	200				
In difference of cost of long valve and pinions........................	375				
Difference in composition (being none required for the long valve)......	125				
In planing, drilling, &c. (which must be wholly connected with the long valve)	150				
	850	× 100 miles..	85,000	0	0
			£300,000	0	0

Thus showing a difference, ***in first outlay,*** in favour of Pilbrow's patent over the present "atmospheric railway" apparatus, in 100 miles, no less a sum than £300,000; and in which it is presumed there can be no difference of opinion, when the two plans are examined and compared, even by the most partial or sceptical:—Fifthly,

* See Mr. Samuda's Evidence before the Committee:—House of Commons.

CHEAPNESS IN WORKING.

	£.	s.	d.
Interest upon capital saved in first outlay (£300,000 per annum	15000	0	0
Wages to engine men and stokers (as 34 is to 11) *	4058	0	0
In composition (being no long valve, and therefore none required for that purpose, £200. being allowed by C. & S. per mile for composition and renewal of travelling apparatus, &c.; one-fourth only is here supposed to be saved)*	5000	0	0
Saving in fuel,—there being only in this case, 11 furnaces to light and keep going between trains, instead of 34, and the fuel at present WASTED by such means being two-thirds of the whole quantity used, where the trains are not very frequent indeed.† When we consider that the engine will only work for 5 minutes to standing still 25 minutes, the fire must be *kept up during this time*, and the waste in getting steam up every day,‡ we shall be underrating, if any thing, by taking only the saving of the two-thirds for 23 engines out of 34, and a proportionate saving in the 11 used; it will stand thus:—As 154 tons of coals are consumed in 80 days§ by $1\frac{3}{4}$ miles of road, (and that working but one way) the saving for 100 miles per annum, at 20*s*. per ton, would be for the two-thirds waste of 23 engines, £18038, and one-third waste upon the 11 engines used, £3009., together	21047	0	0
Mr. Samuda, in his examination, (by Mr. Mereweather) before the House of Commons, stated that "there would be a man per mile extra for attending to the valves:" such not being required where there is no long valve or composition to attend to, the expence would be saved, amounting to, per annum, for 100 men at 12*s*. per week	3120	0	0
In saving of wear, and renewal of 23 boilers, &c.	2300	0	0
In saving of fuel expended on extra leakage, the difference of leakage in the two systems being equal to one-seventh of the power employed; therefore, if we suppose here half the gross fuel used to be usefully expended*	1528	0	0
Total saving for 100 miles per annum in working, as compared with the estimated cost by the present "atmospheric" system	£52053	0	0

* See pamphlet by Messrs. Clegg & Co., p. 21, upon which the above is founded. [John Weale, London.]

† See Mr. Samuda's Evidence.

‡ See Mr. Bergin's Evidence: he states that 42 tons and half of coals were used to get the steam up alone, to 111 tons and half used while the trains were at work.

§ See Mr. Bergin's Evidence.

Now this great saving in *the first outlay of capital,* and the *annual working expenses,* (besides the other obvious vantages, which need only to be known to be appre- ated,) is not a saving upon the *locomotive principle,* but the "*atmospheric principle,*" as now adopted in Ireland, d to be adopted on the Epsom line, which has excited much interest in parliament and the public mind.

It is presumed, after the careful examination and in- estigation, by friend and foe, the atmospheric principle has ad, and the highly favourable conclusions arrived at, hat no one doubts the great advantages and importance of he *present* method,—which shows such an extraordinary aving *over the locomotive* principle, as to amount to nearly *one-half** the present expenditure; AND UPON THIS, the *proposed* method will effect the *further saving,* as above, which alone is very great,—but when compared with the "locomotive" would be infinitely increased.

When, therefore, the simplicity, safety, cheapness, and efficacy are considered, it will, I trust, be acknowledged, that few inventions ever offered the advantages to its proprie- tors, whether a public or private company, that this does; when it is considered how popular the system in its inferior state has been, and how noticed and patronized by the legis- lators of foreign states as well as our own country, and what at *this moment is doing,*—it seems but to require some vigorous, influential, and wealthy individuals to apply it, when its adoption must become a necessity to the railway and commercial interests of the country, as a general system, upon the *four or five thousand* miles of railway made and to be made, the proprietors drawing their revenue from the saving effected upon or over the locomotive prin- ciple of propulsion, *dividing this saving equally* between the railway companies adopting, and the proprietors or licensers

* See Mr. Gibbon's Evidence.

of the patent. According to the calculations published,—throwing off a considerable sum for errors and over-rating,—this *half saving* effected upon 5000 miles, *per annum*, would in round numbers amount to no less a sum than *five millions sterling!* An enormous income for any company, and affording a great margin again for errors and overrating.

I need not state the advantages and applicability of this means of propulsion for CANALS and RIVERS, or even in many cases for COMMON ROADS; for after what has been said and thought of for these purposes, it will suggest itself to every mind conversant with such matters: and the importance in a lucrative point of view needs no comment from me.

The advantages and simplicity of the PNEUMATIC TELEGRAPH, also, will need nothing further said upon it; for it must be evident to every one, that to possess the ability to make the necessary signals with an apparatus at once simple and cheap, is an invaluable addition to the rest.*

With all the necessary information on the subject generally, at command, and with an invitation to inspect the model, to investigate fully, and to apply to me for any information unintentionally omitted, or not sufficiently clear, in the foregoing pages, I leave the subject for the present in the hands of the public, as one of the greatest importance and involving greater benefits and consequences to this nation, and the parties who may introduce it into general operation, than any other invention for many years past.

Tottenham,
December, 1844.

OFFICE,—74, KING WILLIAM STREET, LONDON.

* The "Electric Telegraph" will cost £150. per mile; 100 miles, £15,000.:—See Mr. Samuda's Evidence.

APPENDIX.

"BEFORE science can determine, with accuracy, the superiority of a new plan for applying steam to locomotive engines, it is necessary to ascertain correctly the losses of the present method. It would, for this purpose, be only a source of error to take any particular experiments for data; because the results would vary on every different railway, according to the state of the rails at the time, the weather, the weight drawn, the weight of the engine, form and evaporative power of the boiler, velocity, gradients, and some few other minor circumstances. We must go, therefore, to general principles, (which, correctly ascertained, are of universal application,) and show what are the first losses of the steam, as a moving power in every engine, on whatever line at the same speed and pressure, inherent in its principle of action; independent of those other deductions, which, arising from other circumstances, differ on every railway.

"In considering the *principles* of the old and new methods, we will take the same data for each:—Steam, 75 lbs., or 60 lbs. above the atmosphere; speed, 30 miles an hour; driving wheels, 5 feet; and stroke of piston, 18 inches; such being the practice on the greater number of railways in Great Britain.

"First.—As the piston must travel 504 feet a minute to obtain this speed, the power of the steam will be reduced in proportion as the speed of the piston approaches the velocity of the steam through the port; because if the piston were to recede from the steam at the velocity at which that could, expansively, follow the piston, the steam would produce no effect at all.

"The ports of Messrs. Bury's best engines are as 1 to 15, and the mean opening as $\frac{1}{3}$ more than the half; say $= \frac{1}{23}$ of the piston's area. By this proportion the piston's speed must be mul-

tiplied, to give the velocity at which the steam is required to pass through the port, to move the piston at its required speed of 504 feet in a minute. Thus, $504 \times 23 = 11{,}592$ feet a minute, which is the velocity of the steam required to move the piston 504 feet a minute. The inventor having tried some experiments, to ascertain the first velocity of steam from a boiler to the atmosphere, found that its *initial* velocity is constant; and this is confirmed by the experiments recorded in "Gregory's Mechanics," vol. i, pp. 518, 519. By initial velocity, he means the rate at which the steam is produced at the required density, which is the velocity due to the *power* or pressure indicated by the guage, not the velocity due to its subsequent expansion, which is its duty. But its *expansive* or duty velocity, at the outlet, increases as the $\sqrt{}$ of the density or pressure, (see Gregory also;) and, according to the data there given for determining what such velocity amounts to at different pressures, the simple expansive velocity of steam, at 60 lbs. above the atmosphere, will be 104,490 feet in a minute.

"It follows, then, that if the speed of the piston be such as to require the velocity of the steam's entrance to be 11,592 feet per minute, without taking any advantage from that velocity by direct impingement, the power will suffer in proportion as the required velocity approaches to the natural velocity. Therefore, as 104,490 is to 11,592, so is 60 lbs. per square inch to that which is to be deducted from 60 lbs. for this first loss, the remainder being what the piston receives; and the deduction being the difference between the pressure in the boiler and in the cylinder. Therefore, the first deduction will be on the *positive* side of the piston, (104,490 : 11,592 : : 60) 6·876; or, $60 - 6{\cdot}876 = 53{\cdot}124$. The deduction being here 6·876 lbs.

"Secondly.—A deduction must also be made from the original force, or first power of the steam, for the resistance on the *negative* side of the piston from the steam which is escaping; because the action of the piston is so rapid that the used steam cannot get out of the way in time, and must therefore offer, from its elasticity, considerable impediment. Now, the usual size of the orifice

of the blast pipe is but $\frac{1}{23}$ of the area of the piston. (See "M. de Pambour's Practical Treatise upon Locomotion," p. 246.) This orifice, having to serve both cylinders, becomes but $\frac{1}{46}$ of their united areas; and, therefore, would require the steam to pass through at the speed of 23,184 feet per minute; and, though its own velocity would cause it to pass at the rate of 104,490 feet per minute, yet, being an expansive fluid, only part can, at one time, take this velocity; and it resists the piston in its return, not only by its simple *initial* resistance, but by the *increments* of *expansion*. For instance, we will say, that the moment the eduction valve is opened, the resistance is equal to 60 lbs., and at the termination equal, and then only, to 0. The mean resistance wouid be $=$ 30 lbs.; but as the natural action of the steam would be to its constrained, or forced action, as 104,490 : 23,184, the resistance would be 6·876. To this must be added the further resistance of expelling the contents of the cylinder below the atmospheric point; that is, of that which only equalled the atmosphere; because what we have before considered had relation only to the expansive steam *above* the atmosphere. Now, to expel air or vapour at the rate of 23,084 feet per minute will require a pressure of about 3 lbs. per square inch, as the velocities increase as the $\surd$ of the pressures, and therefore *vice versa*. (See Gregory, vol. 1, p. 519.) Now, as 104,490 : $\surd 60$: : 23,184 : 1·719 $=$ 2·954961; and thus in practice the total resistance of such a piston at such speed will be 6·876 + 2·954961 $=$ 9·830961 lbs.

"Thirdly.—A deduction must be made for the various *frictions* of the engine. And when we consider how tightly a piston must be packed to work at 60 lbs. above the atmosphere, that it travels 504 feet a minute, and that every minute the large slides are opened and shut 672 times, $=$ 11·2 times *every second*, with 60 lbs. on every square inch; the deductions for the pistons, rods, and stuffing boxes, slides, guides, slings, &c. cannot be computed at less than one-seventh of the force (60 lbs.) $=$ 8·57.

"Fourthly.—A deduction must be allowed for loss of power occasioned by the practice of letting in the steam before the

stroke is completed; thereby not throwing away this steam, but throwing away part of the power of the last let in, by *opposing* it before it has done *all* the duty it would assuredly otherwise do. This may fairly be taken at one-fifteenth of the whole = 4 lbs. It is not inferred that this practice is an error in science; on the contrary, it is advantageous to throw away thus much to gain more, or rather to save a greater loss than is fouud to attend a different practice; yet a deduction must, nevertheless, be made, though the least evil of the two, and here it is 4 lbs.

"Fifthly.—A further deduction should be made for the irregularity of motion, and the jerking effect the opening and closing of the valves must have upon the production of vapour and the velocity of its action. But as there appear no data or experiments to found a calculation upon, it is passed without making a deduction, though there is no doubt of its being prejudicial to economy of working.

These several deductions then amount to

$$(6{\cdot}876 + 9{\cdot}83 + 8{\cdot}57 + 4) = 29{\cdot}276 \text{ lbs.}$$

which leave *effective* force (60—29·276)=30·724 lbs. per square inch.

"Thus, in the present method of applying steam to locomotives, there is a first loss of 29·276 lbs. even when the pressure is as high as 60 lbs. above the atmosphere, and which loss is an inherent defect in the system, from which there seems no escape; for many engines, where larger proportions of valves, slides, &c., have been tried, have been realtered to their former dimensions. There is, in all sciences and mechanical actions, a mean of best effect in relation to *all the results required*, and this mean appears now to be obtained in the dimensions of the engine parts of locomotives."

"The inventor is aware, in regard to the first deduction, that if the cubic space, made by the action of the piston while steam is entering, is filled only with steam of the lesser density of 53·124 lbs., then this quantity only being thus *used*, the *duty* of the engine does not suffer to such extent, from the peculiarity

there examined, but simply the *power*. But if the piston's action, just before the closing of the valve, is rendered, by the peculiar qualification of the crank's action, so slow that the steam gets up to the full density, then is the loss as before stated, because the steam, before being sent out of the cylinder, has acquired its maximum density; though *during its* action the average density could not exceed 53.124 lbs. The inventor is willing to make such deduction from this (first) item as shall be deemed sufficient for engines that cut off at an earlier part of the stroke.

"The exact loss in effect from each separate cause here stated, has never been determined by accurate experiments. Those proportions, therefore, are given by general rules, that seemed to the inventor near the mark. But however much engineers may differ on the way in which the whole is made up, few practical men will doubt the total amount, in opposition to the authority of Professor Vignoles, eminent alike for his theoretical knowledge and practical experience. In his late lectures on civil engineering, he observes: "Not only must the steam be generated to a given pressure to produce that power (30 miles an hour), but with sufficient rapidity to continue it; and, in keeping up a high velocity, it must be, as it were, crammed into the cylinders, so as to produce the greatest possible effect in the least possible time; and this is the reason why high velocities are so very expensive, as the same effect might be produced by one-fourth the quantity of steam, if sufficient time were given to expand it."—See *Mining Journal*, 9th April, 1842.

"There is much originality in the mode by which the talented inventor accounts for the loss of power of the present locomotive engines. The first to establish this method of determining it, some *general principle* had long been wanted to ascertain the primary loss simply in the agent itself, applicable without distinction, to every locomotive engine at the same speed and pressure, independent of the load, and separate from that great diversity of construction in railways which, mixed together, render indispensable expensive experiments on each line to compute its own particular loss of locomotive power. Had accurate and distinct

experiments been made on the more scientific and precise plan here given, unmixed with the ever-changing losses different on every line, one broad principle, of much practical value, had been long since given to science; and standing out in its own distinct lines, apart from those other figures with which it has hitherto been jumbled, would probably have led earlier to economical improvements to avoid so great a loss in the present defective method of applying the prime mover. The accuracy of Mr. Pilbrow's theory is amply confirmed by the foregoing extract from Professor Vignoles' Lectures, supplied by the writer, after he had received the calculations. It will be seen, for instance, that if (instead of determining the loss from the initial pressure only, which is nearly all the present locomotive engines can receive), we calculate the loss upon the power the expansive duty of steam would give at the same pressure, (60lbs.) = 132lbs. (could it be used expansively, as it can by the new discovery) we find the loss amounts to (33 — 132 =) 99lbs., or three-fourths, as the Professor states; because one-fourth only, (99 — 132 =) 33lbs. is left available; and this is but 2·276lbs. more than the effective power (30·724 lbs.) found (at p. 7,) by Mr. Pilbrow's principle of calculation; near enough, when spread over his several items, of loss, to test the accuracy of a new theory of computation, made independent of any corroborative authority. Thus, in round numbers, a loss of one-half of the initial is a loss of three-fourths of the whole expansive duty.

"As the lectures referred to are the most recent on the subject, and embrace all the present improvements in locomotive science, the loss of three-fourths may be considered authentic. But facts, which are incontrovertible, attest the truth, both of the Professor's statement, and Mr. Pilbrow's theory. The Cornish lifting-engines, whose duty is the only real standard of comparison in the world, do now perform the same duty as the locomotives, with less than one-fourth of the fuel; and these returns are kept too accurately, and have been before the public too long, and subjected to too many examinations by disinterested parties, to be open to further doubt.

"In comparing the duty of locomotive engines with marine or stationary engines, the difference of pressures is frequently lost sight of. In the former, the steam of 60 lbs. above the atmosphere; in the latter, 6 lbs. at most, which, cut off, seldom give, with the vacuum, a greater mean than 17 lbs. on the inch. But even with this great gain in pressure, the best locomotive now running, at 30 miles an hour, with steam at 60 lbs., does not perform the duty of the worst land engine. This, however, would not be a just or scientific comparison, if it did. What duty ought the locomotive (and other) engines to do with steam at 60lbs. expanded to the lowest? This is the only fair standard of comparison, and this is only found by the lifting-engines in Cornwall, the *average* duty of one of which (Fowey Consols) was shown, by the accurate tables of Mr. Wickstead, C. E., to be only 2·28 lbs. cf coals per horse-power per hour; but when the immense chain of pumps (three times the length of St. Pauls) and other parts of the enormous mass of machinery, were in better condition, the consumption of fuel did not exceed 1·28 lbs. per horse-power per hour.—(*Mining Journal* of the 17th of October, 1840.) Now, if the steam could be applied to the same advantage, and be expanded to the same extent in locomotive as it is in Cornish engines, the former ought not to consume more than 1·28 lbs. of coals per horse-power per hour, because it has not so vast an extent of moving parts to be kept in order.

"These facts, then, clearly prove that the present system of applying steam, generally, is *as a principle*, radically defective, being evidently fitted only for a very slow moving machine; for the Cornish lifting engines are the slowest in the world, the average speed of piston being only 50·027 feet a minute. When this speed is increased to 200 feet a minute, as in the marine engine, the duty immediately falls off, and the consumption of fuel increases in proportion; and when it is still further increased to 500 feet a minute, as in the locomotive engine, there is found a still greater loss of duty, and a greater waste of fuel, increasing as the squares of the speed of the piston. The science of Civil Engineering, therefore, is far in advance of the science of Steam;

and the capabilities of rapid travelling on railways are greatly beyond the present imperfect means of using them to the utmost limits; for, to make the piston of a locomotive engine travel 750 instead of 500 feet a minute, would cause so great a waste of fuel as to render it impracticable. These facts, therefore, fully justify Professor Vignoles' statement, that the necessity of producing 'the greatest possible effect in the least possible time, is the reason why high velocities are so very expensive, as the same effect might be produced by one-fouth the quantity of steam, if sufficient time were given to expand it.' "

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